



Europäisches Patentamt
European Patent Office
Office européen des brevets

⑪ Publication number:

0 060 085
A1

⑫

EUROPEAN PATENT APPLICATION

⑬ Application number: 82301088.9

⑮ Int. Cl. 3: G 02 B 5/172
C 03 B 37/02

⑭ Date of filing: 03.02.82

⑬ Priority: 06.03.81 JP 31152/81
08.07.81 JP 105571/81

⑰ Applicant: Hitachi, Ltd.
5-1, Marunouchi 1-chome
Chiyoda-ku Tokyo 100(JP)

⑭ Date of publication of application:
15.09.82 Bulletin 82/37

⑰ Inventor: Katsuyama, Toshio
Hitachiowada Apartment House D202
47-1, Akatsukidai 1-chome Hachioji-shi(JP)

⑭ Designated Contracting States:
DE FR GB NL

⑰ Inventor: Matsumura, Hiroyoshi
Komamushidai 70-3 284-61, Kubo
Hidakamachi Iruma-gun Saitama-ken(JP)

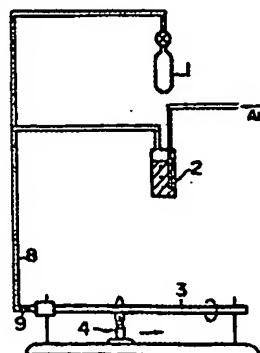
⑰ Inventor: Suganuma, Tsuneo
17-5, Nakaara-5-chome
Tokorozawa-shi(JP)

⑰ Representative: Williams, Trevor John et al.
J.A. KEMP & CO, 14 South Square Gray's Inn
London WC1R 5EU(GB)

⑯ Infrared optical fiber.

⑰ Solid or hollow infrared optical fiber of high stability and small light transmission loss is produced from halides and/or hydrides of elements constituting calcogenide glass as starting materials by MCVD process with less chance for contamination with impurities and with unnecessary for melting for a prolonged time for homogenization.

FIG. 1



EP 0 060 085 A1

Croydon Printing Company Ltd.

BEST AVAILABLE COPY

INFRARED OPTICAL FIBER

1 BACKGROUND OF THE INVENTION

The present invention relates to a process for producing optical fiber capable of transmitting infrared beam.

5 Heretofore, optical fiber is produced from materials of silicate glass, but the materials of silicate glass have such a disadvantage that they transmit only light beams of up to wavelength of about 2 μm and absorb substantially all other beams of 10 longer wavelength by absorption due to lattice vibration. Thus, beams of wavelength of 10.6 μm from a CO_2 laser for use, for example, in laser surgery and laser welding, etc. cannot be transmitted through the fiber of silicate glass. Accordingly, search has been so far made for 15 materials capable of transmitting beams of wavelength from about 2 μm to about 20 μm , and as a result calcogenide glass has been regarded as a promising material for the said range of wavelengths. For example, "Infrared Physics, 1965, Vol. 5 p.p. 69 - 80" discloses 20 infrared optical fiber of As-S glass. The conventional optical fiber of calcogenide glass is produced from powder of such metal as As, S, Ge, P, etc., or calcogen as a starting material by melting for a prolonged time. Thus, the conventional process has such a 25 disadvantage that impurities contained in the starting

1 material powder of metal or calcogen are transferred
into product glass, thereby increasing light trans-
mission loss. Furthermore, the conventional process
has more chance of contamination by impurities during
5 the melting, and also requires substantial time for
melting and homogenizing the powder of metal or calcogen.

The optical fiber is in such a structure
that the core is made from a material of higher refractive
index than that for the clad surrounding the core to
10 utilize total reflection at the interface between
the core and the clad to transmit beams. However,
when a beam of a high output level, for example, 100 W,
such as CO₂ laser beam is transmitted therethrough,
the core material itself reaches such a high temperature
15 as 100° - 400°C due to the absorption of beams by the
core material. Thus, there appear such phenomena that
the core material undergoes thermal breakage or deterio-
ration of mechanical strength. Furthermore, considerable
heat generation takes place particularly at the end
20 face of optical fiber, for example, due to fine dirts
thereon or due to fine irregularity thereon, and special
care is taken for its protection. Consequently, there
has been a restriction to the power level of input
beams.

25 On the other hand, MCVD process is well
known as one of the conventional processes for producing
optical fiber of silicate glass. According to the
MCVD process, a glass film serving as a clad and a

- 1 core, or a glass film serving as a core is deposited onto an inner wall of a glass tube of quartz, etc. by the so-called CVD process utilizing chemical vapor reaction, then the glass tube is heated, thereby
- 5 collapsing the hollow part and forming a rod-like optical fiber preform, and the preform is drawn with heating, thereby forming optical fiber, as disclosed in so many publications, for example, US Patent No. 4,203,743; Japanese Laid-open Patent Application No.
- 10 29953/76, etc.

The following references are cited to show the state of art; i) Infrared Physics, 1964, Vol. 4 p.p. 213 - 221, ii) Infrared physics, 1965, Vol. 5, p.p. 69 - 80, iii) US Patent No. 4,203,743, iv) Japanese Laid-open Patent Application No. 29953/76, and v) The Bell System Technical Journal, 1964, Vol. 43, p.p. 1783 - 1809.

SUMMARY OF THE INVENTION

- 20 An object of the present invention is to provide a process for producing infrared optical fiber with low transmission loss, where the said problems in producing infrared optical fiber from calcogenide glass, that is, the problems of contamination of impurities and melting for a prolonged time have been solved.
- 25

Another object of the present invention is to provide a process for readily producing infrared

1 optical fiber where the said problem of heat generation
has been solved.

The foregoing objects can be attained according to the present process for producing infrared optical fiber, which comprises i) a step of introducing into a glass tube a gas containing a halide and/or a hydride of elements constituting calcogenide glass as starting material, that is, a halide and a hydride of metal, particularly at least one element selected from the group consisting of Si, Ge, As, P and Sb, and a halide or a hydride of at least one calcogen element selected from the group consisting of S, Se and Te, and heating the glass tube, thereby depositing the calcogenide glass, that is, a compound of said metal, etc. and said calcogen element, onto the inside wall of the glass tube, and ii) a step of heating and drawing the resulting glass tube into fiber. In the step ii), the glass tube is heated at a high temperature to collapse the tube, and then drawn at a much higher temperature, whereby solid optical fiber can be obtained. Hollow optical fiber can be also obtained by heating and drawing the glass tube in a hollow state without collapsing, and dry air or infrared transmission liquid can be filled into the hollow fiber. In the case of solid fiber, the glass tube can be heated and drawn as such.

According to the present process, infrared optical fiber of high performance can be produced

- 1 without the problems, that is, without any fear of contamination of impurities and any necessity for melting for a prolonged time.

It is essential in the present process to

- 5 use a halide or a hydride of the metal, etc. or calcogen element as a starting material in place of the powder of the metal, etc. or calcogen element as in the conventional process.

Furthermore, according to the present process,

- 10 glass breakage due to heat generation, which has been a bottleneck in the prior art, can be avoided by using hollow fiber, and infrared optical fiber capable of transmitting a high energy level beam can be produced thereby. This is based on transmission of HE_{11} mode
- 15 in a hollow waveguide of hollow optical fiber.

Optical fiber of high infrared transmittance can be obtained by making the clad from calcognide glass of high refractive index and high infrared transmittance while using air as the core. A large

- 20 number of pseudo-transmitted modes (leaky modes) can be transmitted through such hollow fiber. Different from the conventional optical fiber with core of high refractive index, the pseudo-transmitted modes are waves transmitted while producing transmission loss,
- 25 among which the lowest order mode (HE_{11} mode) has the least transmission loss.

According to "The Bell System Technical Journal, 1964, Vol. 43, p.p. 1783 - 1807", the

1 transmission loss α of HE_{11} mode is given by the following formula:

$$\alpha = \left(\frac{2.405}{2\pi} \right)^2 \frac{\lambda^2}{a^3} \cdot \frac{\frac{1}{2}(n^2+1)}{\sqrt{n^2-1}} \quad \dots \quad (1)$$

5

where n represents a refractive index of glass, λ wavelength of light and a a radius of hollow part.

When $n = \sqrt{3}$ in formula (1), α takes the minimum value, i.e. $\alpha = 1.8 \lambda^2/a^3$ (dB). The refractive index of 10 calcogenide glass is usually $n = 2.5$, where the transmission loss is $2.01 \lambda^2/a^3$ (dB). When the wavelength of light is $10.6 \mu\text{m}$ and $a = 2 \text{ mm}$, the transmission loss will be 0.028 dB/m , which is small enough, as compared with the ordinary glass and crystal, and such 15 optical fiber can be used satisfactorily as a transmission path for high energy level beams.

Another feature of the hollow fiber produced according to the present process is use of calcogenide glass of low transmission loss as a clad. Substantially 20 all of the energy of the beams transmitted through the fiber passes through the hollow part, and thus the electromagnetic field passing through the clad is small even with a high incident power, and even if the clad has transmission loss of 1 dB/m , the temperature 25 increase of the glass by absorption is small.

The said step i) can follow the well known MCVD process except for the starting material. When solid fiber is produced, the said step ii) can also

- 1 follow the well known MCVD process. When hollow optical fiber is produced, the glass tube from the step 1) is drawn at such a heating temperature and in such a drawing ratio not to cause collapsing of
- 5 the glass tube while keeping the glass tube in a hollow state. The necessary heating temperature and the drawing ratio can be determined by simple preliminary test.

Any material can be used for the glass tube,
10 so long as it can be drawn at a high temperature together with the deposited calcogenide glass. Usually, quartz glass, Pyrex glass, lead glass, etc. are used. When solid fiber is produced, collapsed optical fiber preform with the said glass tube as a crust can be drawn as
15 such, but when the crust is removed from the preform by guiding or chemical etching and then the preform freed from the crust is drawn, infrared optical fiber consisting only of calcogenide glass can be obtained. In the latter case, any material can be used for the
20 glass tube, so long as it can be collapsed at a high temperature together with the deposited calcogenide glass.

When the starting material is in a gaseous state at room temperature in the said step 1), it
25 can be directly introduced into the glass tube, but when it is in a liquid state at room temperature, it is bubbled with an inert gas such as Ar, etc., and the generated vapor is introduced into the glass tube

1 together with the inert gas as a carrier gas.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram showing an
5 apparatus for depositing calcogenide glass onto the
inside wall of a glass tube by local heating of the
glass tube according to one embodiment of the present
invention.

Fig. 2 is a schematic diagram showing an
10 apparatus for depositing calcogenide glass onto the
inside wall of a glass tube by uniform heating of
the glass tube.

Fig. 3 is a schematic diagram showing an
apparatus for depositing calcogenide glass onto the
15 inside wall of a glass tube whose heating part for
reaction is separated from a deposition part.

Fig. 4 is a cross-sectional view of hollow
fiber having a calcogenide glass layer on the inside
wall of a glass tube.

20 Fig. 5 is a schematic view showing an apparatus
for depositing calcogenide glass onto the inside wall
of a glass tube by local heating of the glass tube
according to another embodiment of the present invention.

25 DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described in
detail below by way of a case of producing As-S glass
fiber, referring to the drawings.

-1 In the production of As-S fiber glass, AsCl₃ and H₂S are used as starting materials. AsCl₃ is in a liquid state at room temperature, and thus a bubbler 2 is used as shown in Fig. 1, AsCl₃ is placed 5 in the bubbler 2 and bubbled with Ar. AsCl₃ is introduced into a glass tube 3 through a gas line 8 together with Ar. On the other hand, H₂S is in a gaseous state at room temperature, and is led to the glass tube 3 through the gas line 8 from a cylinder 1 directly. 10 That is, a raw material gas of AsCl₃, H₂S and Ar in mixture is led to the glass tube 3 through the gas line 8 in the arrow direction 9.

Then, the raw material gas is heated in the glass tube 3 and thermally decomposed to deposit As-S 15 onto the inside wall of the glass tube 3. Heating can be carried out by an electric furnace or a gas burner. In Fig. 2 heating is carried out by a gas burner 4.

In Fig. 1, the glass tube 3 is locally heated by the gas burner 4, and the gas burner 4 is moved 20 in the longitudinal direction of the tube at the same time to obtain a deposit film of uniform composition and uniform thickness in the longitudinal direction. It is also possible to rotate the tube to form a uniform deposit in the circumferential direction.

25 Such local heating is however one example, and the glass tube 3 can be heated to the full length of glass tube by an electric furnace 5, as shown in Fig. 2, or a heating part 6 for chemical vapor reaction

1 of the raw material gas can be separated from a deposi-
tion part 7 usually at a lower temperature than that
of the heating part, as shown in Fig. 3. Anyway, the
raw material gas mixture is introduced into the glass
5 tube 3 through the gas line 8 in the arrow direction
9.

The glass tube onto whose inside wall As-S
glass is deposited in the foregoing manner is heated
and drawn into fiber. In the production of solid fiber,
10 usually the As-S glass-deposited glass tube is heated
and collapsed to form optical fiber preform, and then
the preform is drawn at a much higher temperature,
whereas in the production of hollow fiber, the As-S
15 glass-deposited glass tube is directly heated and drawn
so that no collapsing can occur. In the production of
solid fiber, the As-S glass-deposited glass tube can
be also directly heated and drawn without forming the
preform.

First of all, the production of solid fiber
20 will be described in detail below:

The As-S glass-deposited glass tube is
further heated for collapsing. Heating for the collapsing
can be local heating by a burner, where the heating
part is moved in the longitudinal direction of the glass
25 tube. In that case, heating can be uniformly carried
out in the circumferential direction of the glass
tube by rotating the glass tube. Collapsing can
proceed under the inside pressure of the glass tube

1 equal or a little inferior to the atmosphere, but the
As-S glass is liable to vaporize, the tube inside is
made vacuum and the ends of the tube are sealed before
the collapsing is carried out. The thus prepared
5 solid rod is called "preform".

Then, the preform is drawn into fiber in
the same manner as in the conventional drawing of a
preform of quartz glass fiber. In that case, the
resulting fiber has oxide glass, which is the constituent
10 of the glass tube 3, as a crust. By removing the oxide
glass from the preform by guiding or chemical etching
beforehand, optical fiber consisting only of As-S
glass can be obtained.

The foregoing process is directed to the
15 production of As-S glass fiber having a uniform com-
position in the radial direction. Clad-type fiber
of double layer structure consisting of a core of high
refractive index and a clad of low refractive index,
or graded index-type fiber whose refractive index is
20 gradually increased from the peripheral part toward
the center can be produced by changing the composition
in the radial direction in the following manner.

The composition can be changed in the radial
direction by reciprocating the burner of heating the
25 glass tube while moving in the longitudinal direction
of the glass tube several times in the longitudinal
direction, while changing the composition of raw
material gas to the glass tube at every reciprocation.

1 or at a specific reciprocation. The composition of
raw material gas can be changed by changing a mixing
ratio of $AsCl_3$ to H_2S , or by adding other additive
such as $GeCl_4$ thereto to change the concentration. }
10

5 Production of hollow fiber will be described
in detail below.

The $As-S$ glass-deposited glass tube is drawn
in the same manner as in the conventional drawing of
quartz glass fiber. In that case, heating temperature
10 and drawing ratio must be so selected as not to collapse
the glass tube. The thus produced optical fiber is
hollow fiber having $As-S$ glass on the inside wall of
the glass fiber, as shown in Fig. 4, where numeral 10
is an air core, numeral 11 a calcogenide layer, and
15 numeral 12 a drawn glass tube.

In the foregoing, only the case of using
 $AsCl_3$ and H_2S as the starting materials has been
described for both solid fiber and hollow fiber.
Besides the foregoing starting materials, AsH_3 , $AsBr_3$,
20 AsI_3 , etc. can be also used for As , and S_2Cl_2 , SCl_2 , etc.
for S .

In the foregoing, description has been made
only of the fiber of $As-S$ glass. The present process
is however not limited only to the $As-S$ glass fiber,
25 but also to other calcogenide glass fiber. Other
calcogenide glass than the $As-S$ glass includes: (1)
 $Ge-Sb-S$; (2) $Ge-Sb-Se$; (3) $Ge-As-S$; (4) $Ge-As-Se$;
(5) $Ge-S-P$; (6) $Ge-Se-P$, etc. Typical composition

- 1 of calcogenide glass for use in the present process is combinations of at least one of Si, Ge, As, P and Sb with at least one of S, Se, and Te. Besides the foregoing elements, Cl, Br or I can be added thereto.
- 5 The present process is applicable not only to the compositions as defined above, but also to calcogenide glass of other compositions as defined above.

As described above, the present process has such advantages as less chances for contamination

- 10 of a product with impurities and unnecessary for melting for a prolonged period for homogenizing the composition, and is very effective for production of optical fiber with low transmission loss.

15 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

GeCl_4 and SbCl_5 were used as compounds of metal, etc, and Se_2Cl_2 as a calcogen compound as starting materials, and the apparatus shown in Fig. 5 was used.

- 20 GeCl_4 was placed in a bubbler 2 and bubbled with Ar. SbCl_5 was placed in a bubbler 2' and bubbled with Ar. Se_2Cl_2 was placed in a bubbler 2" and bubbled with Ar. A raw material gas of GeCl_4 , SbCl_5 and Se_2Cl_2 carried by carrier Ar gas was introduced into a glass
- 25 tube 3 of lead glass (outer diameter: 14 mm, inner diameter: 12 mm) through a gas line 8 in the arrow direction 9. GeCl_4 , SbCl_5 and Se_2Cl_2 were all in a liquid state at room temperature and were bubbled at

1 20°C. The composition of the raw material gas was controlled by bubbling of Ar to 43 mg/s of GeCl_4 , 30 mg/s of SbCl_5 and 137 mg/s of Se_2Cl_2 .

Chemical vapor reaction was carried out by

5 using an oxygen-hydrogen burner 4 reciprocating at a rate of 0.2 cm/s in the longitudinal direction of the glass tube 3, while rotating the glass tube 3 at 40 rpm. Heating temperature was found to be 600°C by an optical pyrometer. After the heating oxygen-hydrogen burner 4 was reciprocated in the longitudinal direction of the glass tube 3 by 50 repetitions, the glass tube was fused at about 800°C to collapse the glass tube into a preform.

Then, the thus obtained preform was drawn 15 at 800°C into optical fiber with a Ge-Sb-Se glass part having an outer diameter of 50 μm and a crust glass part having an outer diameter of 150 μm .

The glass tube consisted of lead glass, and the calcogenide glass consisted of 28 mol.%Ge - 20 12 mol.%Sb - 60 mol.%Se. The thus obtained optical fiber had light transmission loss of 0.1 dB/m at the wavelength of 10.6 μm , and thus the infrared optical fiber with considerably smaller light transmission loss than that of the conventional optical 25 fiber was obtained.

Example 2

A Ge-Sb-Se glass film was deposited on the

- 1 inside wall of a glass tube in the same manner as in Example 1, except that the glass tube of lead glass having an outer diameter of 14 mm and an inner diameter of 13 mm was used and the heating oxygen-hydrogen
- 5 burner 4 was reciprocated in the longitudinal direction of the glass tube by 100 repetitions.

The calcogenide glass film-deposited glass tube was heated in an electric furnace at 800°C and drawn into hollow glass fiber. The hollow glass fiber

- 10 had an outer diameter of 4 mm, an inner diameter of 1.5 mm and a calcogenide glass film thickness of 300 μ m.

The lead glass of the glass tube consisted of 57 mol.% SiO_2 - 12 mol.% Na_2O + K_2O - 30 mol.% PbO ,

- 15 and the deposited calcogenide glass had the same composition as in Example 1.

The thus obtained hollow infrared optical fiber had light transmission loss of 0.7 dB/m at the wavelength of 10.6 μ m, and had a temperature elevation

- 20 by only a few tens of degree °C even with an incidental CO₂ laser beam of 50 W, and thus the infrared optical fiber with a high stability and small light transmission loss, as compared with those of the conventional optical fiber was obtained.

25

Example 3

In the foregoing Example 1, solid optical fiber having a uniform composition in the radial

1 direction was produced, whereas in the present Example 3, glass fiber having changing composition in the radial direction was produced by using the same apparatus as shown in Fig. 5 and used in Example 1.

5 In the present Example 3, 43 mg/s of GeCl_4 , 60 mg/s of SbCl_5 and 137 mg/s of Se_2Cl_2 as the starting materials were used up to 25th repetition of reciprocal movement of the burner in the longitudinal direction of the glass tube, and 43 mg/s of GeCl_4 , 30 mg/s of SbCl_5 and 137 mg/s of Se_2Cl_2 were used from 26th repetition to 50th repetition. Other conditions were the same as in Example 1.

The thus obtained preform was drawn into fiber.

15 An optical fiber having light transmission loss of 0.01 dB/m at the wavelength of 10.6 μm was obtained.

20 It seems that considerably smaller light transmission loss in Example 3 than in Example 1 is due to the fact that the present fiber consisted of a core and a clad and had no substantial influence by the surrounding glass tube.

25 The thus obtained clad-type fiber had a core diameter of 50 μm , a clad thickness of 50 μm and total diameter of 150 μm , and the core consisted of 28 mol.%Ge - 12 mol.%Sb - 60 mol.%Se, and the clad consisted of 23.5 mol.%Ge - 12 mol.%Sb - 64.5 mol.%Se.

Obviously many modifications and variations

1 of the present invention are possible in the light of
the above teachings. It is therefore to be understood
that within the scope of the appended claims the
invention may be practised otherwise than as specifically
5 described.

CLAIMS:

1. A process for producing infrared optical fiber which comprises:
 - i) a step of introducing a gas containing halides and/or hydrides of elements constituting calcogenide glass into a glass tube and heating the glass tube, thereby depositing onto the inside wall of the glass tube calcogenide glass resulting from chemical vapor reaction, and
 - ii) a step of heating the glass tube from the step i) and drawing the tube into fiber at a high temperature.
2. The process according to Claim 1, wherein the calcogenide glass is a compound of at least one element selected from the group consisting of Si, Ge, As, P and Sb, and at least one element selected from the group consisting of S, Se and Te.
3. The process according to Claim 1 or 2, wherein the step ii) comprises heating the glass tube, thereby forming a solid optical fiber preform, and drawing the preform into solid fiber at a high temperature.
4. The process according to Claim 1 or 2, wherein the step ii) comprises drawing the glass tube into hollow fiber without collapsing the glass tube.
5. The process according to Claim 3, wherein the preform is drawn into fiber at a high temperature after the crust of the preform has been removed.

0060085

1/2

FIG. 1

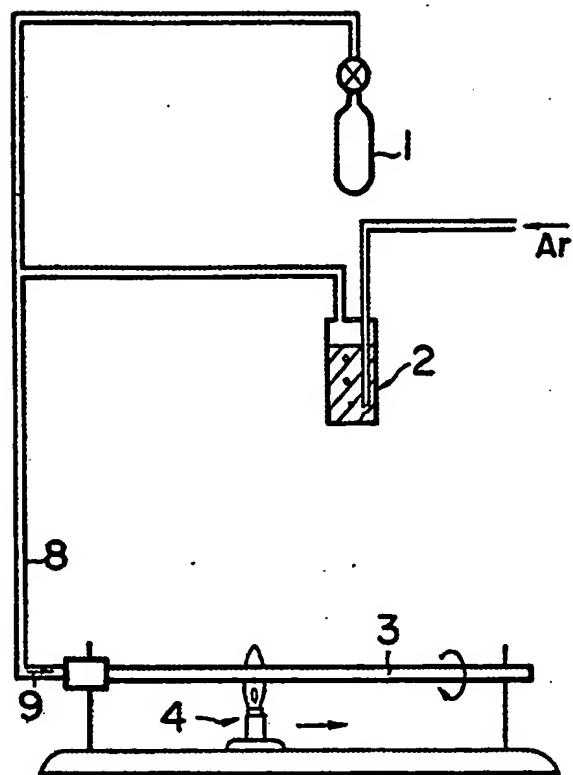


FIG. 2

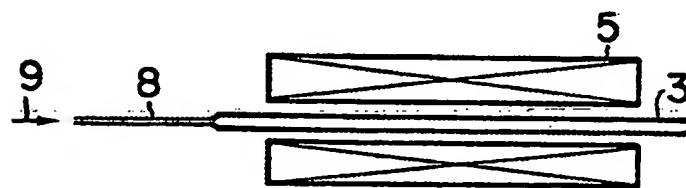


FIG. 3

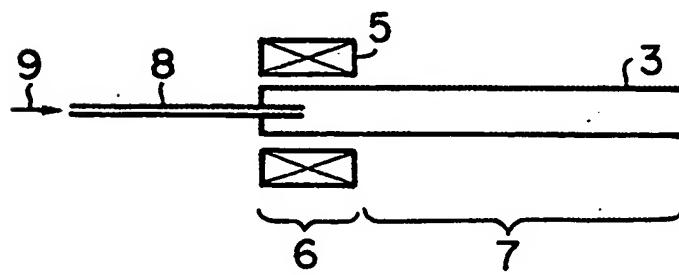


FIG. 4

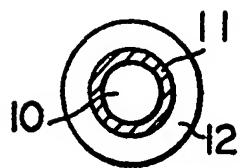
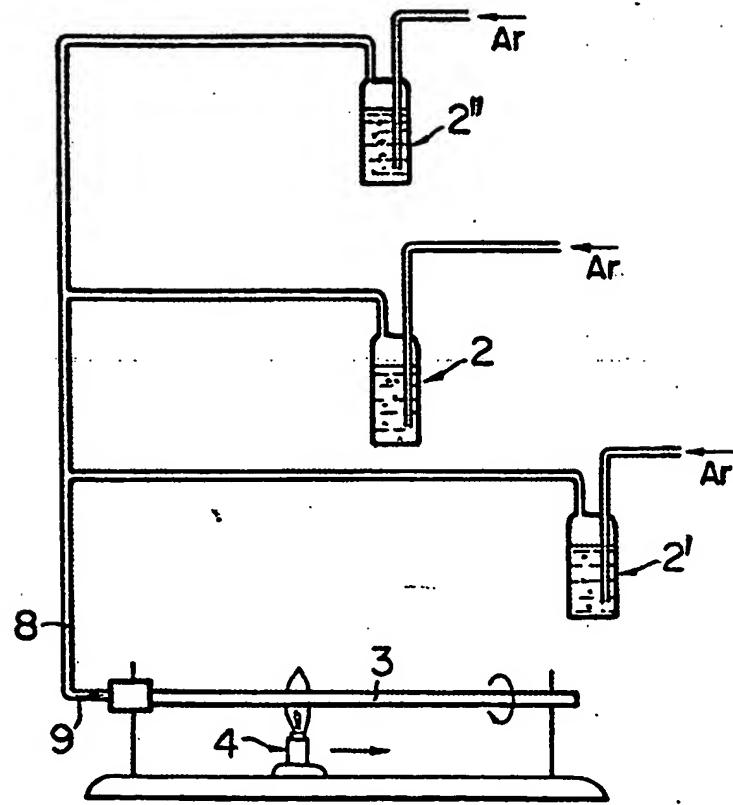


FIG. 5





European Patent
Office

EUROPEAN SEARCH REPORT

0060085

Application number

EP 82 30 1088

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Classification of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X	US-A-4 188 089 (G. GLIEMER ROTH) * claims 1,2,4,6,7,12 *	1-3	G 02 B 5/172 C 03 B 37/02
A	US-A-3 980 459 (TINGYE LI) * summary; figures *	1	
A	FR-A-2 384 722 (I.S.E.C.) * claims *	1	
A	DE-B-2 546 162 (JENAER GLASWERK) * columns 3,4 *	1	
A,D	US-A-4 203 743 (T. SUGANUMA et al.) * abstract *	1	
	-----		TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
			G 02 B 5/172 C 03 B 37/02
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	17-06-1982	PFAHLER R.	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : technological background O : non-written disclosure P : intermediate document	
X : particularly relevant if taken alone	Y : particularly relevant if combined with another document of the same category	A : member of the same patent family, corresponding document	
Z : document cited for other reasons			

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.